RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #15

Enhanced Squitter Reception Test Procedures Revision and New Material for Appendix I

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SUMMARY
This Working Paper presents a revision to the Enhanced Squitter Reception Test Procedures that separates the performance required of A2 class equipment from that of A3 class equipment. The intent is to base the required performance of A2 class equipment on the performance measured using an 8 MHz sampling rate implementation and to use the 10 MHz sampling rate implementation results to set the required performance for A3 class equipment. In addition, this Working Paper includes new text for Appendix I to address the effect of sampling rate on reception performance.

Introduction

This Working Paper presents a revision to the Enhanced Squitter Reception Test Procedures that separates the performance required of A2 class equipment from that of A3 class equipment. The intent is to base the required performance of A2 class equipment on the performance measured using an 8 MHz sampling rate implementation and to use the 10 MHz sampling rate implementation results to set the required performance for A3 class equipment. The test procedure revision is simply to include 3 success criteria tables for each applicable test, one for each equipment class. The required reception probability for each test point is yet To Be Determined. However, the measured performance using the center sample technique has been provided in the A1 equipment class tables, and the measured performance using the 10 MHz multisampling technique has been provided in the A3 equipment class tables. The performance data using the 8 MHz sampling rate needs to be supplied by Lincoln Labs since the Tech Center does not have an 8 MHz implementation. The measured performance data are included as input in determining the required minimum probability.

This Working Paper also includes new text for Appendix I to address the effect of sampling rate on reception performance.

Enhanced Squitter Reception Test Procedures Revision

The following text contains the revised sections 2.4.4.4.2.4 through 2.4.4.4.2.6 since these are the affected sections. Proposed changes are red. Text that is part of this working paper but not intended for the MOPS is <mark>highlighted</mark>.

2.4.4.4.2.4   Combined Preamble and Data Block Tests with Mode A/C Fruit

Purpose/Introduction:

The following tests measure the performance of the equipment under test in decoding the extended squitter preamble and data block overlapped with Mode A/C fruit. The test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a series of tests are conducted with the number of Mode A/C fruit overlaps set to one to five respectively for A2 and A3 equipment class. For A1 equipment class, the tests are limited to a maximum of three Mode A/C fruit overlaps. For each test, the timing of the overlapping fruit is uniformly pseudo randomly distributed across the preamble and data block for seven different relative power levels. The fruit power levels will be set according to the test step being conducted and will remain constant while each of the seven extended squitter power levels are tested. **T** samples are taken at each power level. Squitters that

are declared to be correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the extended squitter transmission. Any difference between the content of the decoded extended squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters.

The observed probability of correct squitter reception for each relative power level is computed. An average value of the performance across all power levels is computed and compared to the required performance to determine success or failure for the test.

Step 1:   Verification of Operation of Equipment Under Test

Connect the extended squitter signal source and set the power level at the receiver input equal to the MTL limit required for the UUT equipment class:

−79 dBm for A1 equipment class or,

−79 dBm for A2 equipment class or,

−84 dBm for A3 equipment class.

Inject the extended squitter signal **T** times and record the extended squitters that are declared to be output as error free. Compare the decoded content of each extended squitter with the known content of the injected extended squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 90% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2:   Test with One Mode A/C Fruit Overlap

Set the extended squitter signal source as specified in Step 1.

Set the power level of one Mode A/C fruit source at the receiver input to the value corresponding to the UUT equipment class:

−67 dBm for A1 or A2 equipment class or,

−72 dBm for A3 equipment class.

Activate the Mode A/C fruit source so that the fruit is pseudo randomly distributed across the extended squitter preamble and data block as specified in 2.4.4.4.2.1.

Inject the extended squitter waveform **T** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step six times while increasing the extended squitter power level by 4 dB with each iteration.

Calculate the average probability of reception and the total number of undetected errors across the seven power levels.

Step 3:   Test with Two Mode A/C Fruit Overlaps

Repeat Step 2 with two fruit overlaps set to the following power levels and record the results:

> -69 and –65 dBm for A1 or A2 equipment class or,

> -74 and –70 dBm for A3 equipment class.

Step 4:   Test with Three Mode A/C Fruit Overlaps

Repeat Step 2 with three fruit overlaps set to the following power levels and record the results:

> -71, -67 and –63 dBm for A1 or A2 equipment class or,

> -76, -72 and –68 dBm for A3 equipment class.

Step 5:   Test with Four Mode A/C Fruit Overlaps

Repeat Step 2 with four fruit overlaps set to the following power levels and record the results:

> -73, -69, -65 and –61 dBm for A2 equipment class or,

> -78, -74, -70 and –66 dBm for A3 equipment class.

Step 6:   Test with Five Mode A/C Fruit Overlaps

Repeat Step 2 with five fruit overlaps set to the following power levels and record the results:

> -75, -71, -67, -63 and –59 dBm for A2 equipment class or,

> -80, -76, -72, -68 and –64 dBm for A3 equipment class.

Step 7:   Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2.4.4.4.2.4a, Table 2.4.4.4.2.4b or Table 2.4.4.4.2.4c.

Editorial Note: The highlighted table values represent the measured results from performing the bench tests and are provided as input into determining the required minimum probabilities. They will not be included in the final MOPS. This is also the case for the subsequent tables in the document. The measured results for A1 equipment were derived using a 10 MHz Center Sample Enhanced Decoder. The measured results for A2 equipment were derived using an 8 MHz Multiple Sample Enhanced Decoder simulation. The measured results for A3 equipment were derived using a 10 MHz Multiple Sample Enhanced Decoder.

Table 2.4.4.4.2.4a: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – A1 Equipment Class

Number of Fruit	1	2	3
	.94	.67	.55
Minimum Probability	TBD	TBD	TBD
Max Undetected Errors	1	1	1

Table 2.4.4.4.2.4b: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – A2 Equipment Class

Number of Fruit	1	2	3	4	5
Minimum Probability	TBD	TBD	TBD	TBD	TBD
Max Undetected Errors	1	1	1	1	1

Table 2.4.4.4.2.4c: Success Criteria for Preamble and Data Block Tests with Mode A/C Fruit – A3 Equipment Class

Number of Fruit	1	2	3	4	5
	.97	.96	.95	.9	.89
Minimum Probability	TBD	TBD	TBD	TBD	TBD
Max Undetected Errors	1	1	1	1	1

2.4.4.4.2.5   Data Block Tests with Mode S Fruit

Purpose/Introduction:

The following tests measure the performance of the equipment under test in decoding the extended squitter data content overlapped with Mode S fruit. The

test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a test is conducted with a single Mode S fruit overlap. For this test, the timing of the overlapping fruit is uniformly pseudo randomly distributed across the data block for four different relative power levels. **T** samples are taken at each power level. Squitters that are declared to be correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the extended squitter transmission. Any difference between the content of the decoded extended squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters.

Finally, the observed probability of correct squitter reception for each relative power level is computed.

Step 1:   Verification of Operation of Equipment Under Test

Connect the extended squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Inject the signal **T** times and record the extended squitters that are declared to be output as error free. Compare the decoded content of each extended squitter with the known content of the injected extended squitter. Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 99% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2:   Test with One Mode S Fruit Overlap

Set the extended squitter signal source as specified in Step 1.

Activate the Mode S fruit source so that the Mode S fruit is pseudo randomly distributed across the data extended squitter data block as specified in §2.4.4.4.2.1.2.

Set the Mode S fruit power to 0 dB relative to the Extended Squitter signal level.

Inject the extended squitter waveform **T** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of signal to interference (S/I) of +4, +8, and + 12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the four power levels.

Step 3: Determination of Success or Failure

Compare the results recorded above with the appropriate requirements in Table 2.4.4.4.2.5a, Table 2.4.4.4.2.5b or Table 2.4.4.4.2.5c.

Table 2.4.4.4.2.5a: Success Criteria for Data Block Tests with Mode S Fruit – A1 Equipment Class

Relative Power (S/I) dB	0	+4	+8	+12
	.01	.59	.99	1
Minimum Probability	TBD	TBD	TBD	TBD
Max Undetected Errors	1	1	1	1

Table 2.4.4.4.2.5b: Success Criteria for Data Block Tests with Mode S Fruit – A2 Equipment Class

Relative Power (S/I) dB	0	+4	+8	+12
Minimum Probability	TBD	TBD	TBD	TBD
Max Undetected Errors	1	1	1	1

Table 2.4.4.4.2.5c: Success Criteria for Data Block Tests with Mode S Fruit – A3 Equipment Class

Relative Power (S/I) dB	0	+4	+8	+12
	0	.52	1	1
Minimum Probability	TBD	TBD	TBD	TBD
Max Undetected Errors	1	1	1	1

2.4.4.4.2.6   Re-Triggering Performance

Purpose/Introduction:

The following tests measure the capability of the equipment under test to detect extended squitters that are preceded by lower level Mode S fruit. The test series begins with monitoring the reception performance in the absence of interference to establish that the equipment under test is operating correctly.

Next, a test is conducted with a single Mode S fruit overlap with a varying position. For this test, the timing of the overlapping fruit is uniformly pseudo randomly distributed across the time interval beginning at –112 microseconds and ending at –6 microseconds relative to the leading edge of the P1 preamble pulse of the extended squitter.

Finally, a test is conducted with a single Mode S fruit overlap with a fixed position. For this test, the timing of the overlapping fruit is fixed at –6 microseconds relative to the leading edge of the P1 preamble pulse of the extended squitter.

The re-triggering performance tests are conducted at three different relative power levels. **T** samples are taken at each power level. Squitters that are declared to be correctly received (i.e., received without errors or successfully error corrected) are compared to the known content of the extended squitter transmission. Any difference between the content of the decoded extended squitter and the known content of the injected squitter is recorded as an undetected error and that squitter reception is removed from the count of successfully received squitters. The observed probability of correct squitter reception for each relative power level is computed.

Step 1:   Verification of Operation of Equipment Under Test

Connect the extended squitter signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Inject the signal **T** times and record the extended squitters that are declared to be output as error free. Compare the decoded content of each extended squitter with the known content of the injected extended squitter.   Any differences that are detected are recorded as an undetected error and that squitter reception is deleted from the count of error free receptions.

Calculate the measured probability of correct receptions and the number of undetected errors. The test is passed if the probability of correct receptions is at least 99% and there is no more than one undetected error event.

If this test is successful, proceed to Step 2. Otherwise, the test setup and equipment under test should be checked and Step 1 is repeated.

Step 2:   Re-triggering Test with Varying Position Mode S Fruit

Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Set the extended squitter power to +4 dB relative to the Mode S fruit signal level.

Activate the Mode S fruit source so that the 112-bit Mode S fruit signal is uniformly randomly distributed across the time interval beginning at –112 microseconds and ending at –6 microseconds relative to the leading edge of the P1 preamble pulse of the extended squitter. The timing indicated is the spacing from the leading edge of the P1 pulse of the Mode S fruit to the leading edge of the P1 pulse of the extended squitter.

Inject the extended squitter waveform **T** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of Signal to Interference (S/I) of +8, and + 12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the three power levels.

Compare the results recorded above with the appropriate requirements in Table 2.4.4.4.2.6a, Table 2.4.4.4.2.6b or Table 2.4.4.4.2.6c.

Table 2.4.4.4.2.6a: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – A1 Equipment Class

Relative Power, (S/I) dB	+4	+8	+12
	.13	.74	.96
Minimum Probability	TBD	TBD	TBD
Max Undetected Errors	1	1	1

Table 2.4.4.4.2.6b: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – A2 Equipment Class

Relative Power, (S/I) dB	+4	+8	+12
Minimum Probability	*TBD*	*TBD*	*TBD*
Max Undetected Errors	1	1	1

Table 2.4.4.4.2.6c: Success Criteria for Re-Triggering Test with Varying Position Mode S Fruit – A3 Equipment Class

Relative Power, (S/I) dB	+4	+8	+12
	.13	.93	.99
Minimum Probability	*TBD*	*TBD*	*TBD*
Max Undetected Errors	1	1	1

Step 3:   Re-triggering Test with Fixed Position Mode S Fruit

Connect the Mode S Fruit signal source. Set and verify that the power level at the receiver input is equal to the MTL limit required for the UUT equipment class plus 12 dB:

–67 dBm for A1 or A2 equipment class or,

–72 dBm for A3 equipment class.

Set the extended squitter power to +4 dB relative to the Mode S fruit signal level.

Activate the Mode S fruit source so that the 112-bit Mode S fruit signal has a fixed position at –6 microseconds relative to the leading edge of the P1 preamble pulse of the extended squitter. The 6-microsecond spacing is the time from the leading edge of the P1 pulse of the Mode S fruit to the leading edge of the P1 pulse of the extended squitter.

Inject the extended squitter waveform **T** times and record the receptions that are declared to be error free. Check for undetected errors and adjust as necessary the number of correctly received replies as specified in Step 1. Calculate the measured probability of correct reception and the number of undetected errors.

Repeat the above step for relative powers of Signal to Interference (S/I) of +8, and +12 dB.

Calculate the probability of correct reception and the number of undetected errors for each of the three power levels.

Compare the results recorded above with the appropriate requirements in Table 2.4.4.4.2.6d, Table 2.4.4.4.2.6e or Table 2.4.4.4.2.6f.

Table 2.4.4.4.2.6d: **Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – A1 Equipment Class**

Relative Power, (S/I) dB	+4	+8	+12
	.02	.52	.92
Minimum Probability	*TBD*	*TBD*	*TBD*
Max Undetected Errors	1	1	1

Table 2.4.4.4.2.6e: **Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – A2 Equipment Class**

Relative Power, (S/I) dB	+4	+8	+12
Minimum Probability	*TBD*	*TBD*	*TBD*
Max Undetected Errors	1	1	1

Table 2.4.4.4.2.6f: **Success Criteria for Re-Triggering Test with Fixed Position Mode S Fruit – A3 Equipment Class**

Relative Power, (S/I) dB	+4	+8	+12
	.28	.98	.99
Minimum Probability	*TBD*	*TBD*	*TBD*
Max Undetected Errors	1	1	1

2.4.4.4.3 **Verification of Error Correction Restriction (§)**

Purpose/Introduction:

The enhanced reception techniques are intended to operate in very high Mode A/C fruit environments. For this reason, the sliding window error correction technique **shall** not be used in conjunction with the enhanced techniques since it produces an unacceptably high undetected error rate in these high fruit environments.

> *Note:* *See Appendix I, §I.3.3 and §I.4.3 for more details on error correcting techniques.*

Measurement Procedure:

TBD

Proposed Addition to Appendix I

I.4.1.1   Log Video Samples

The preamble detection process described here operates on data in the form of samples of the log video received waveform. Specifically, the sample rate is 10 samples per microsecond, although other sample rates, including 8 samples per microsecond, have been found to be effective. In developing these enhanced decoding techniques, both an 8 MHz and 10 MHz sampling rate implementation were tested. It was determined that the 10 MHz sampling rate yielded better reception performance. In general, a higher sampling rate will perform better because of more samples for bit and confidence decoding. For this MOPS, the 10 MHz sampling rate implementation was used to establish the reception performance required for A3 equipment class, and the 8 MHz sampling rate implementation was used to set the required performance for the A2 equipment class.